REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

2. REPORT DATE 92-12-23

3. REPORT TYPE AND DATES COVERED Annual (91-12-2 to 92-12-2)

4. TITLE AND SUBTITLE

Effect of Surface Active Materials on Bubble Dynamics in Two-Phase Flow

5. FUNDING NUMBERS

N00014-91-J-1780

6. AUTHOR(S)

Dr. Bruce D. Johnson

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Oceanography Dept.
Dalhousie University
Halifax, Nova Scotia
Canada B3H 4J1

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

Department of the Navy
Office of the Chief of Naval Research
800 North Quincy St. Code 1512A:LAM
Arlington, Virginia
U.S.A. 22217-5000

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Distribution Unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

Our goal in this research is to relate bubble performance in processes such as bubble breaking, dissolution, coalescence and breakup to bubble interfacial character, including surface tension, surface charge and surface rheological properties. This fiscal year we have studied bubble dissolution rates in "clean" fresh water and in sea water samples representing a wide range of biological activities. Previous measurements of bubble dissolution have used water that was equilibrated with a known atmosphere - a process that takes many hours and results in alteration of chemical and biological properties. We have used a novel gas tension method to determine O_2 and N_2 partial pressures in the water phase. Our results indicate that mass transfer rates for dissolution in fresh water coincide with theoretical predictions, but those for sea water are always significantly less and especially at low Reynolds Numbers.

Bubble coalescence and breaking of bubbles at the air-water interface were observed in fresh water and sea water samples. Both process were observed to produce satellite bubbles. For example, millimeter-size bubbles breaking at the air-water interface each produced 20 or more bubbles of greater than 30 μm in diameter.

14. SUBJECT TERMS

Bubble; Bubble Coalescence; Bubble Mass Transfer

15. NUMBER OF PAGES

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
unclassified			

REPORT OF INVENTIONS AND SUBCONTRACTS

(Pursuant to "Patent Rights" Contract Clause) (See Instructions on Reverse Side.)

FORM APPROVED
OMB NO. 0704-0016

1a. NAME OF CONTRACTOR/SUBCONTRACTOR Dr. Bruce D. Johnson	c. CONTRACT NUMBER N00014-91-J-1780	2a. NAME OF GOVERNMENT PRIME CONTRACTOR	c. CONTRACT NUMBER	3. TYPE OF REPORT (check one) ☒ INTERIM ☐ FINAL
b. ADDRESS (include Zip Code) Oceanography Dept, Dalhousie Univ. Halifax, Nova Scotia Canada B3H4J1	d. AWARD DATE (YYMMDD) 91-03-06	b. ADDRESS (include Zip Code)	d. AWARD DATE (YYMMDD)	4. REPORTING PERIOD (YYMMDD) FROM: TO: 2-12-91 to 2-12-92

SECTION I - SUBJECT INVENTIONS

5. "SUBJECT INVENTIONS" REQUIRED TO BE REPORTED BY CONTRACTOR/SUBCONTRACTOR *(If "None", so state)*

a. NAME OF INVENTOR(S) (Last, First, M.I.)	b. TITLE OF INVENTION(S)	c. DISCLOSURE NO., PATENT APPLICATION SERIAL NO. OR PATENT NO.	d. ELECTION TO FILE PATENT APPLICATIONS: UNITED STATES YES	UNITED STATES NO	FOREIGN YES	FOREIGN NO	e. CONFIRMATORY INSTRUMENT OR ASSIGNMENT FORWARDED TO CONTRACTING OFFICER: YES	NO
	None							

f. EMPLOYER OF INVENTOR(S) NOT EMPLOYED BY CONTRACTOR/SUBCONTRACTOR.

i. NAME OF INVENTOR (Last, First, M.I.)	i. NAME OF INVENTOR (Last, First, M.I.)
ii. NAME OF EMPLOYER	ii. NAME OF EMPLOYER
iii. ADDRESS OF EMPLOYER (include Zip Code)	iii. ADDRESS OF EMPLOYER (include Zip Code)

g. ELECTED FOREIGN COUNTRIES IN WHICH A PATENT APPLICATION WILL BE FILED.

i. TITLE OF INVENTION	ii. FOREIGN COUNTRIES OF PATENT APPLICATION

SECTION II – SUBCONTRACTS *(Containing a "Patent Rights" clause)*

6. SUBCONTRACTS AWARDED BY CONTRACTOR/SUBCONTRACTOR. *(If "None", so state)*

a. NAME OF SUBCONTRACTOR(S)	b. ADDRESS (include Zip Code)	c. SUBCONTRACT NO.(S)	d. DAR "PATENT RIGHTS" CLAUSE NO.	DATE (YYMM)	e. DESCRIPTION OF WORK TO BE PERFORMED UNDER SUBCONTRACT(S)	f. SUBCONTRACT DATES (YYMMDD) AWARD	ESTIMATED COMPLETION

SECTION III – CERTIFICATION

7. CERTIFICATION OF REPORT BY CONTRACTOR/SUBCONTRACTOR. *(Not required if* ☐ *Small Business or* ☒ *Non-Profit organization.) (Check appropriate box)*

a. NAME OF AUTHORIZED CONTRACTOR/SUBCONTRACTOR OFFICIAL (Last, First, M.I.) DR. ROBERT O. FOURNIER

b. TITLE ASSOCIATE VICE PRESIDENT (RESEARCH) DALHOUSIE UNIVERSITY

c. I certify that the reporting party has procedures for prompt identification and timely disclosure of "Subject Inventions," that such procedures have been followed and that all "Subject Inventions" have been reported.

SIGNATURE OF AUTHORIZED CONTRACTOR/SUBCONTRACTOR OFFICIAL

DATE (YYMMDD) 92-12-23

Long-Term Goals:

Our long term goal is to determine the effects of natural surface active materials including dissolved salts on bubble dynamics in sea water. In particular, we intend to relate bubble performance in processes such as bubble breaking, dissolution, coalescence, and break-up to bubble interfacial character, including surface tension, surface charge and surface rheological properties.

Near-term objectives include:

1. Developing models to understand the experimental results we have now obtained for bubble mass transfer, bubble coalescence and bubble breaking.

2. Studying bubble coalescence in more detail to determine the contributions of dissolved salts and surface active organic matter in the markedly different behavior of bubble coalescence in sea water and fresh water.

3. Further examining anomalous bubble behavior, e.g., stability against dissolution or breaking, to determine the cause and the frequency of occurrence in natural populations.

Approach:

We are currently modelling our earlier results. For example, our mass transfer results might be described by diffusion through a thick film in series with a normal convective diffusive boundary layer. Experimental studies of coalescence are being treated in two ways, one in which the process is viewed by microscope and film thinning is observed directly, and the other in which bubbles are maintained in suspension and precisely manipulated into contact. In this second configuration surface tension and electrophoretic mobility can also be measured and related to contact time.

Tasks Completed:

This fiscal year we have studied bubble dissolution rates in sea water and in "clean" fresh water. The sea water samples represented a wide range of biological activity and included filtered samples of coastal sea water and samples of phyto-plankton culture medium.

Results of the mass transfer measurements have been modelled using normal mass transfer relationships.

Studies of bubble coalescence and breaking in distilled water and in sea water were conducted in samples representing a wide range of biological activities. This work led to development of a new system for studying bubble coalescence - a system that permits measurement of coalescence time and in addition bubble/water surface tension and bubble electrophoretic mobility.

Results:

This fiscal year we have studied bubble dissolution rates in sea water samples representing a wide range of biological activities. Unlike previous studies we have characterized both N_2 and O_2 concentrations in the water phase. The basis of our method is measurement of gas tension, which is the sum of the partial pressures of gases dissolved in water. Of this total pressure, about 99% is N_2 and O_2. Thus, we have measured O_2 by wet chemical methods and inferred N_2 from gas tension. Knowing the partial pressures of these two gases, we have been able to use normal mass transfer relationships to compare with our experimental results. We have found that bubble dissolution in distilled water behaves very nearly as predicted, but for dissolution in sea water mass transfer is significantly impeded (figure 1). This reduction in mass transfer is especially great for bubbles in actively growing phytoplankton suspensions.

A second set of experiments has focused on bubble coalescence and breaking. We have found that in both processes smaller bubbles may be produced. In sea water as many as 25 bubbles of 30 microns or greater are formed when millimeter sized bubbles break at the air-water interface. Observed differences between fresh water and sea water may help in understanding variability of bubble dynamics in terms of effects of dissolved salts and natural surfactants.

Accomplishments:

The most important accomplishment is development of the method and instrumentation for determining the concentration of N_2 in water - an accomplishment that has allowed measurements of bubble mass transfer rates in well controlled experiments. Previous measurements of bubble dissolution have used water that was equilibrated with a known atmosphere - a process that takes many hours and results in alteration of natural surfactants and changes in biological activity. Results show that bubble mass transfer in sea water is significantly below that predicted from theoretical considerations.

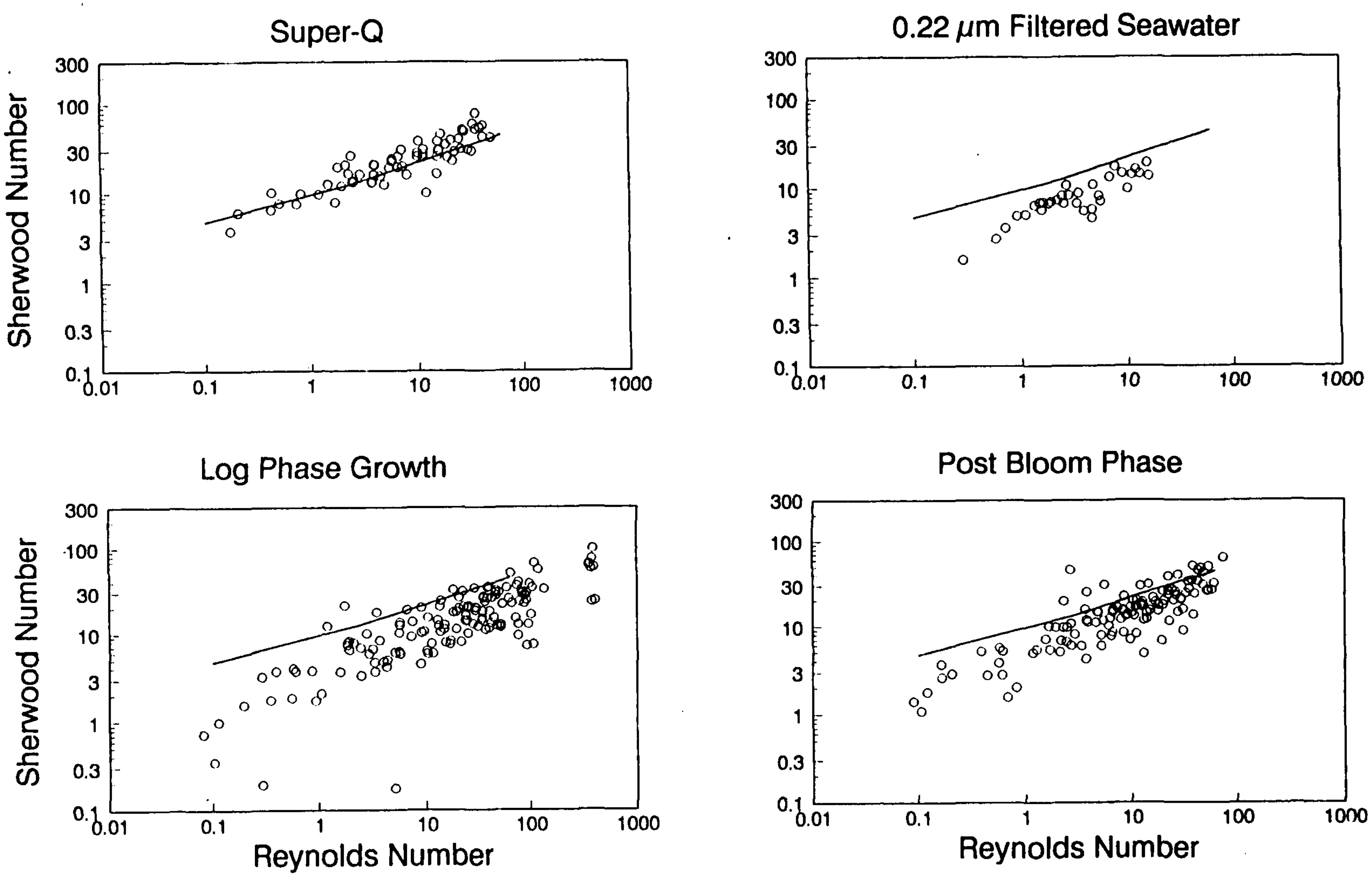

Fig. 1: Mass transfer for bubbles showing the effect of fresh water and seawater. Super-Q is distilled water passed through activated carbon an ion exchange resin, and a 0.2 μm pore size filter. Seawater samples include filtered (0.22 μm) seawater collected in early October from the Dalhousie Aquatron intake line; and culture medium from both the log growth phase and post bloom (stationary) phase of a Chatoceros gracilis culture.